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(54) **CONSTRAINT PROCESSING AS AN ALTERNATIVE TO FLIGHT MANAGEMENT SYSTEMS**

(71) Applicant: **Richard E. Heinrich**, Marion, IA (US)

(72) Inventor: **Richard E. Heinrich**, Marion, IA (US)

(73) Assignee: **ROCKWELL COLLINS, INC.**, Cedar Rapids, IA (US)

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G06F 19/00 (2011.01)
G08G 5/00 (2006.01)
G05D 1/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G08G 5/003*** (2013.01); ***G05D 1/00*** (2013.01); ***G08G 5/0047*** (2013.01); *G08G 5/0039* (2013.01)

(58) **Field of Classification Search**
USPC 701/416, 423, 120, 122, 411–412, 414; 244/175; 342/65; 706/15, 19; 709/240
See application file for complete search history.

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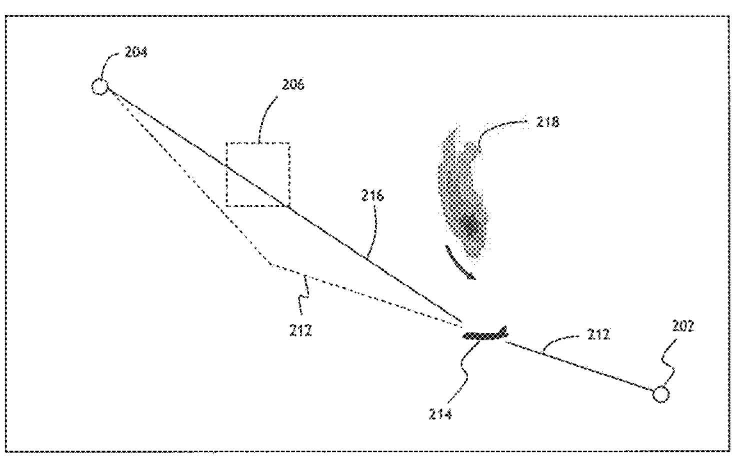
Primary Examiner — Cuong H Nguyen
(74) *Attorney, Agent, or Firm* — Angel Gerdzhikov; Donna Suchy; Daniel Barbieri

(57) **ABSTRACT**

Methods and apparatus for providing trajectory planning for an aircraft based on constraint processing are disclosed. The method may take into consideration the dynamic or real-time operational and environmental factors, and utilizes constraint processing to provide trajectory optimizations between the end points of the flight. The trajectory planning method may be performed utilizing a computer or processor onboard the aircraft. The method may include receiving a starting location and an ending location for a phase of flight of the aircraft; receiving a set of constraints from multiple systems and sensors for the phase of flight of the aircraft, wherein operations of the aircraft during the phase of flight are subject to the set of constraints; and analyzing the set of constraints to determine an optimal trajectory between the starting location and the ending location, the optimal trajectory is determined based on compliance with the set of constraints.

20 Claims, 4 Drawing Sheets



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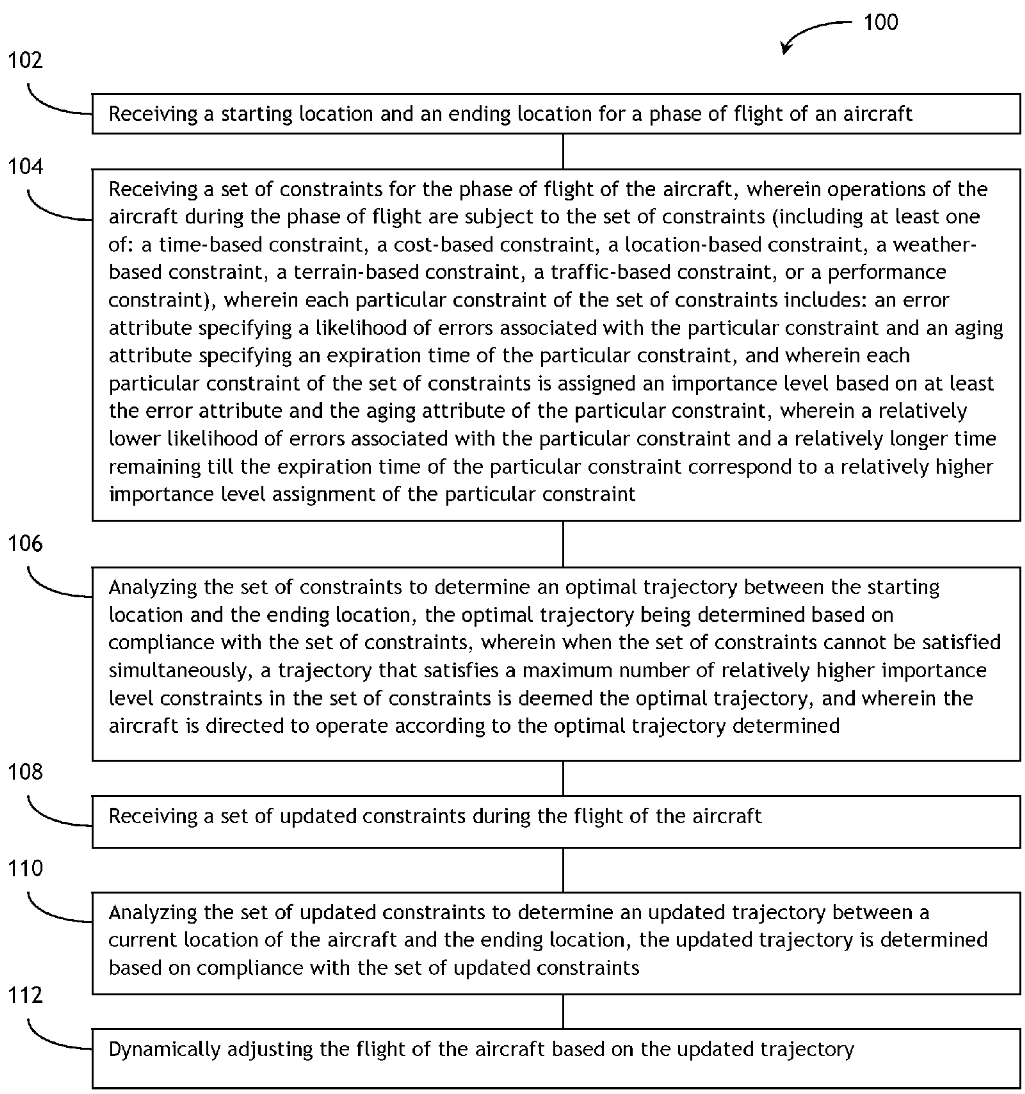
100
102
Receiving a starting location and an ending location for a phase of flight of an aircraft
104
Receiving a set of constraints for the phase of flight of the aircraft, wherein operations of the aircraft during the phase of flight are subject to the set of constraints (including at least one of: a time-based constraint, a cost-based constraint, a location-based constraint, a weather-based constraint, a terrain-based constraint, a traffic-based constraint, or a performance constraint), wherein each particular constraint of the set of constraints includes: an error attribute specifying a likelihood of errors associated with the particular constraint and an aging attribute specifying an expiration time of the particular constraint, and wherein each particular constraint of the set of constraints is assigned an importance level based on at least the error attribute and the aging attribute of the particular constraint, wherein a relatively lower likelihood of errors associated with the particular constraint and a relatively longer time remaining till the expiration time of the particular constraint correspond to a relatively higher importance level assignment of the particular constraint
106
Analyzing the set of constraints to determine an optimal trajectory between the starting location and the ending location, the optimal trajectory being determined based on compliance with the set of constraints, wherein when the set of constraints cannot be satisfied simultaneously, a trajectory that satisfies a maximum number of relatively higher importance level constraints in the set of constraints is deemed the optimal trajectory, and wherein the aircraft is directed to operate according to the optimal trajectory determined
108
Receiving a set of updated constraints during the flight of the aircraft
110
Analyzing the set of updated constraints to determine an updated trajectory between a current location of the aircraft and the ending location, the updated trajectory is determined based on compliance with the set of updated constraints
112
Dynamically adjusting the flight of the aircraft based on the updated trajectory

FIG. 1

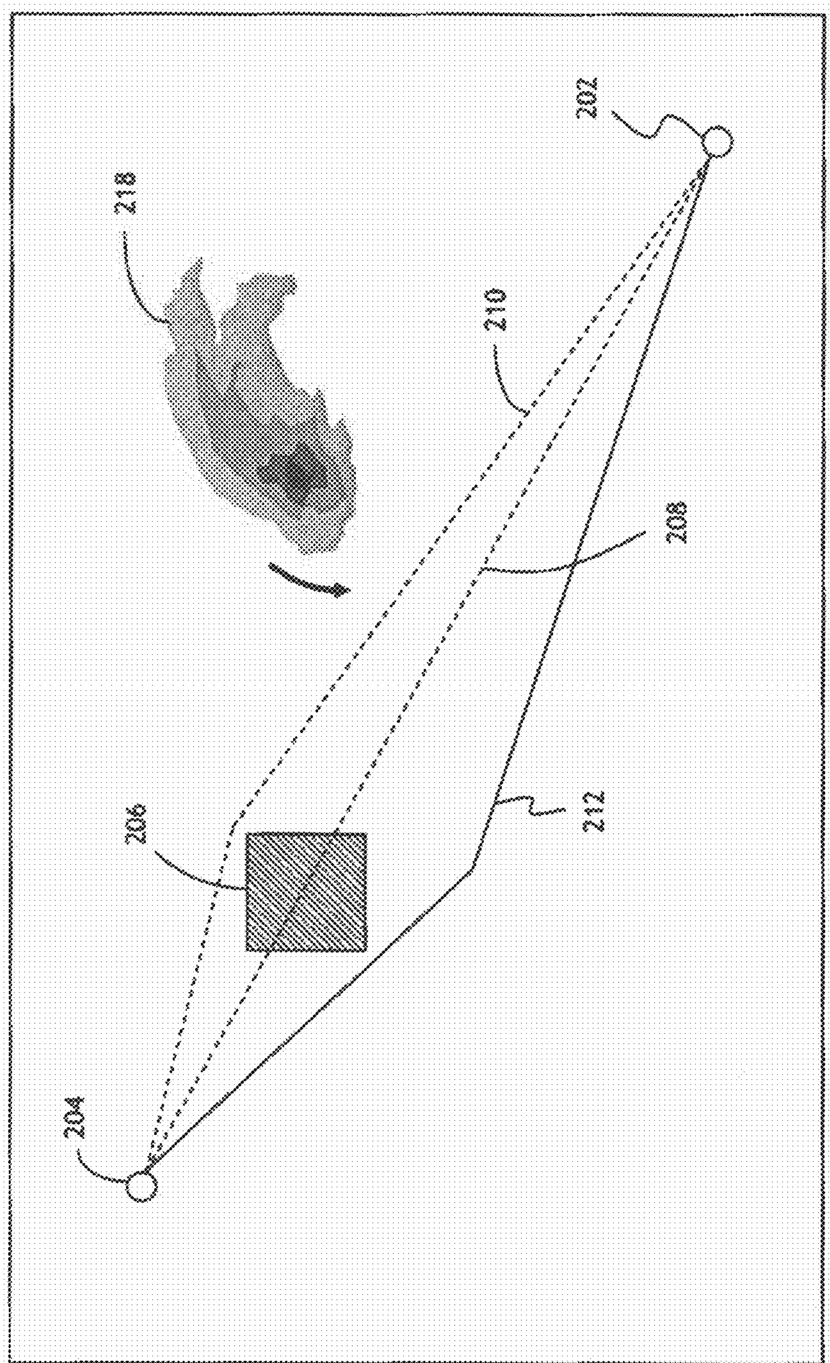

FIG. 2

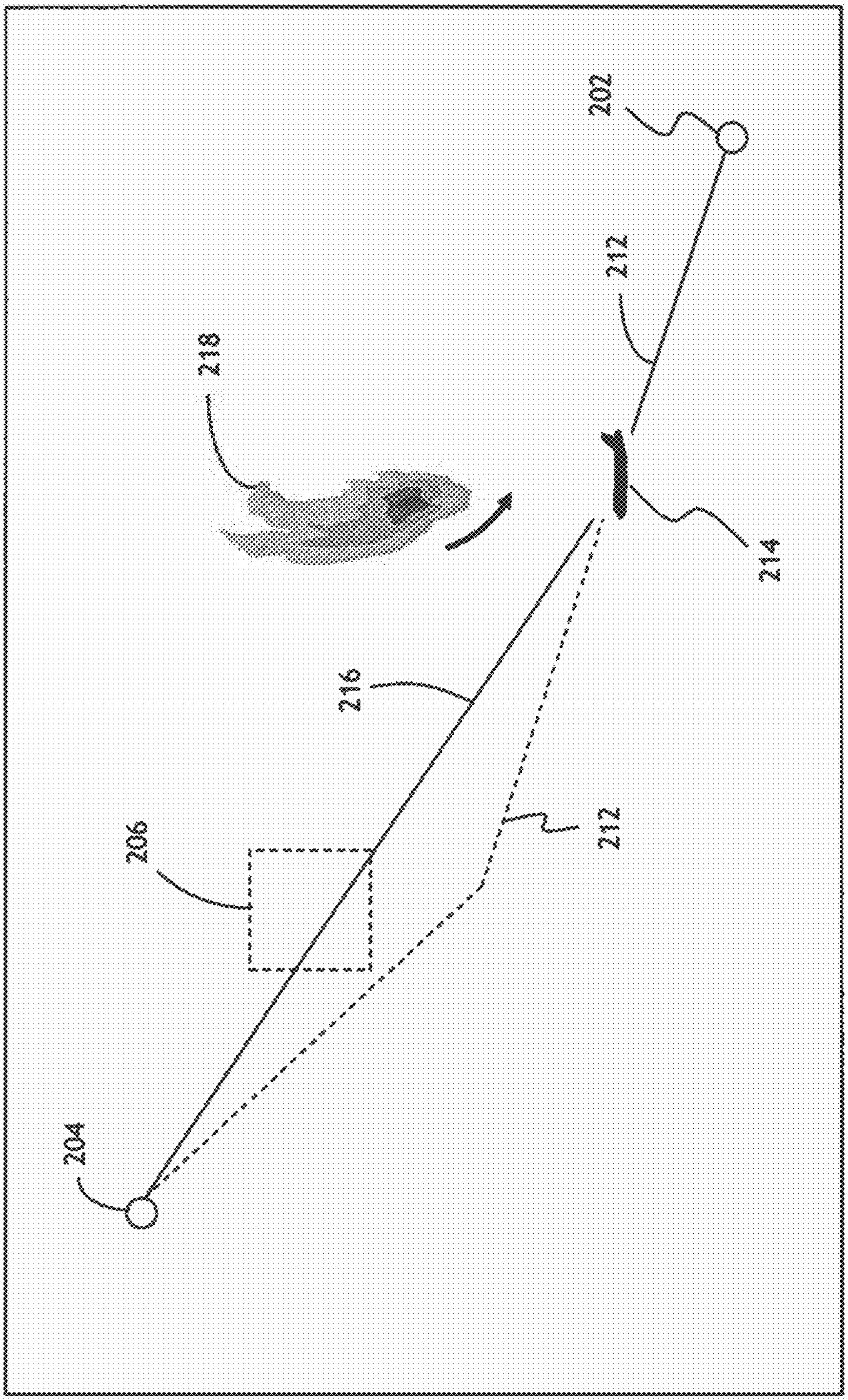

FIG. 3

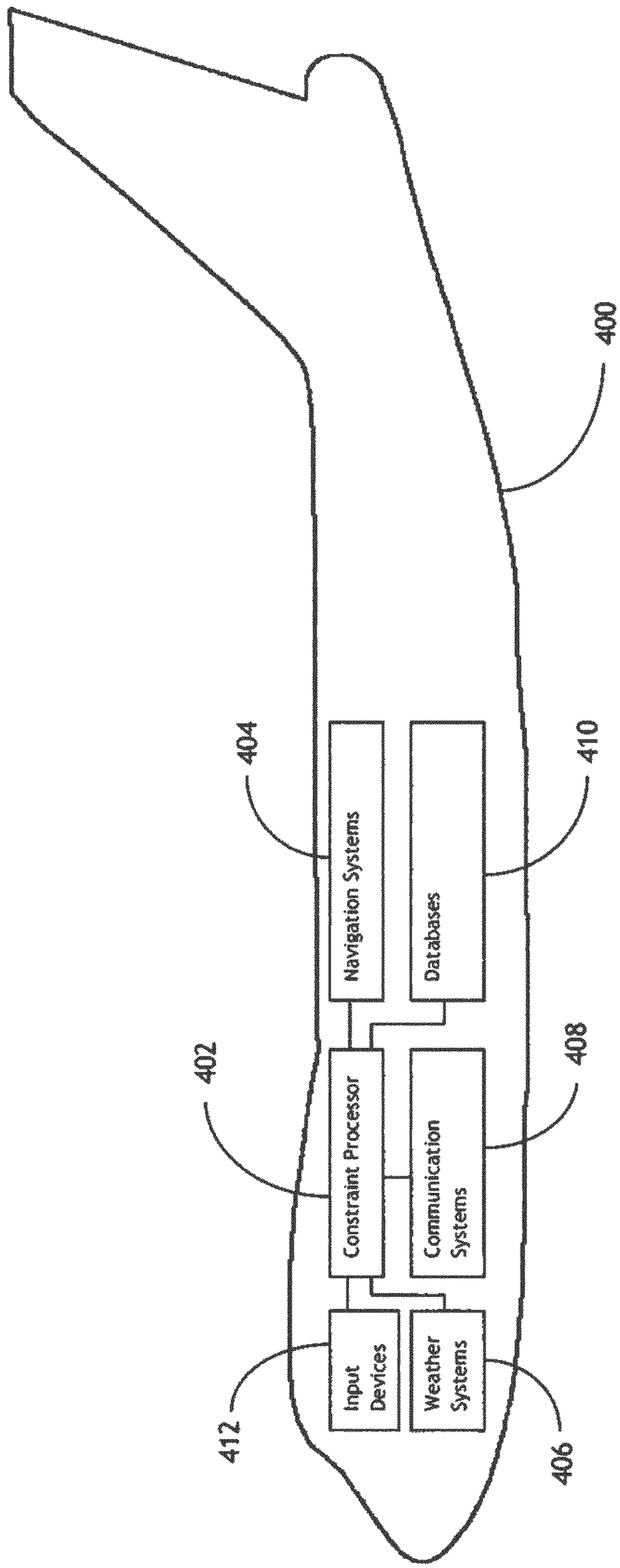
400
404
Navigation Systems
410
Databases
402
Constraint Processor
408
Communication Systems
412
Input Devices
406
Weather Systems

FIG. 4

CONSTRAINT PROCESSING AS AN ALTERNATIVE TO FLIGHT MANAGEMENT SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation of and claims the benefit of U.S. Non-Provisional application Ser. No. 13/109,428, filed May 17, 2011. Said U.S. Non-Provisional application Ser. No. 13/109,428, filed May 17, 2011 is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

The present disclosure relates generally to aircraft flight management and more particularly to system for providing trajectory planning based on constraint processing.

BACKGROUND

Providing a safe operating environment for day to day operations is an essential requirement for an air traffic control system. A traditional air traffic control system may coordinate flight planning between various airspace users. This effort may be focused on ground based systems that are managed to support user requested trajectories. However, with the increase in air traffic, requirements for improved environmental performances, and the need for flexibility in planning and execution, the amount of processing required of such air traffic control systems increases rapidly.

A flight management system, or FMS, is a computer system onboard an aircraft that may automate certain in-flight tasks. For example, a conventional FMS may use various sensors to determine the position of the aircraft (e.g., utilizing satellite positioning, inertial navigation, radio navigation or the like), and guide the aircraft along trajectories plan pre-established by air traffic controllers. However, the ground systems that prepare such trajectories and the aircraft that executes these trajectories may be rigid and rule based. They may not be able to take into consideration any dynamic or real-time operational and environmental factors. Therein lies the need for a trajectory planning method that takes such factors into consideration.

SUMMARY

The present disclosure is directed to a system and method for providing aircraft centric trajectory planning based on constraint processing. Instead of merely executing flight plans pre-established by air traffic controllers, the aircraft centric trajectory planning takes into consideration the dynamic or real-time operational and environmental factors, and utilizes constraint processing to provide trajectory optimizations between the end points of the flight. The trajectory planning method may be performed utilizing a computer or processor onboard the aircraft. The method may include receiving a starting location and an ending location for a phase of flight of the aircraft; receiving a set of constraints from multiple systems and sensors for the phase of flight of the aircraft, wherein operations of the aircraft during the phase of flight are subject to the set of constraints; and analyzing the set of constraints to determine an optimal trajectory between the starting location and the ending location, the optimal trajectory is determined based on compliance with the set of constraints.

A further embodiment of the present disclosure is directed to a trajectory planning method for an aircraft in flight to an end location. The method may include receiving a set of constraints during the flight of the aircraft; analyzing the set of constraints to determine an optimal trajectory between a current location of the aircraft and the end location, the optimal trajectory is determined based on compliance with the set of constraints; and dynamically adjusting the flight of the aircraft based on the optimal trajectory.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention claimed. The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate an embodiment of the invention and together with the general description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The numerous objects and advantages of the present disclosure may be better understood by those skilled in the art by reference to the accompanying figures in which:

FIG. **1** is a flow chart illustrating a method for trajectory planning method for an aircraft based on constraint processing;

FIG. **2** is an illustration depicting an optimal trajectory determined based on a given set of constraints;

FIG. **3** is an illustration depicting an updated trajectory determined based on a set of updated constraints; and

FIG. **4** is a block diagram illustrating a constraint processing system for providing trajectory planning for an aircraft.

DETAILED DESCRIPTION

Reference will now be made in detail to exemplary embodiments of the disclosure, examples of which are illustrated in the accompanying drawings.

The present disclosure is directed to a system and method for providing aircraft centric trajectory planning based on constraint processing. Instead of merely executing flight plans pre-established by air traffic controllers, the aircraft centric trajectory planning takes into consideration the dynamic or real-time operational and environmental factors, and utilizes constraint processing to provide trajectory optimizations between the end points of the flight. Aircraft centric trajectory planning in accordance with the present disclosure provides decision support tools for pilots and air traffic controllers with abilities to manage changes and to resolve system constraints. Furthermore, aircraft centric trajectory planning may also reduce the amount of processing required of the ground control systems.

Referring generally to FIGS. **1** through **3**. FIG. **1** shows a method **100** for providing aircraft centric trajectory planning based on constraint processing, and FIGS. **2** and **3** are illustrations depicting optimal trajectories determined based on the given constraints. When utilizing the method **100** for planning a trajectory for a phase of flight of the aircraft, only the end points (e.g., the starting and the ending locations) and a set of constraints may need to be specified. The trajectory planning method **100** may analyze the set of constraints to determine an optimal trajectory between the end points. For instance, step **102** may receive the starting location **202** and the ending location **204** as input from air traffic controllers, pilots or the like. It is contemplated that the starting and ending locations may refer to departure and destination locations. Alternatively, if the flight of an aircraft is divided into multiple phases, the end points of each particular phase may be referred to as a starting location and an ending location (for that particular phase), and the method **100** may be utilized to determine a trajectory between the end points of any given phase of flight.

The flight of the aircraft may be subject to various constraints. Such constraints may be based on traffic, weather and terrain in the airspace that the aircraft is currently operating within. Other constraints may include, for example, known or detected obstacles in the direction of travel that need to be avoided, availabilities of airspaces (e.g., temporary flight restrictions, special use airspaces or the like), aircraft performance constraints (e.g., when utilizing performance-based navigations), and various other factors. Furthermore, different aircraft operators may have different operational constraints/objectives. For example, a scheduled operator may be subject to time-based constraints where the aircraft may need to minimize its flight time or arrive at its destination within a pre-specified time range. In another example, an unscheduled operator may be subject to cost-based constraints where the aircraft may need to minimize its fuel consumption. It is contemplated that the various constraints described above are merely exemplary; an aircraft may be subject to other types of constraints, or a combination of constraints, without departing from the spirit and scope of the present disclosure.

The trajectory planning method **100** may receive the set of constraints that the aircraft is subjected to in step **104**. For instance, traffic information may be provided as input to the trajectory planning method **100** via automatic dependent surveillance-broadcast (ADS-B), traffic information services-broadcast (TIS-B), traffic radars, ground traffic control stations or the like. Weather information may be provided as input to the trajectory planning method **100** via onboard weather radars, ground linked weather systems or the like. Similarly, terrain information may be provided as input to the trajectory planning method **100** via terrain databases or terrain detection radars or the like. Furthermore, potential obstacles in the direction of travel of the aircraft may be provided as input to the trajectory planning method **100** via obstacle databases (e.g., for known obstacles) or radar detections. In addition, if the aircraft is operating under a performance-based navigation specification, then the performance constraints/requirements may also be provided as input to the trajectory planning method **100**.

Additional constraints that may be provided as input to the trajectory planning method **100** may include location-based airspace constraints. For example, a database may record the restricted airspace locations and provide them as input to the trajectory planning method **100**. It is contemplated that certain airspace restrictions may be changed dynamically, and therefore the trajectory planning method **100** may be configured to receive up-to-date or real-time constraints via various wired or wireless communication means (e.g., radio communications or Notice To Airmen (NOTAMs)). Such airspace constraints may include, for example, temporary flight restrictions, special use airspace, sector boundaries, curfews, airport conditions or the like.

FIG. **2** is an illustration depicting some potential trajectories between the starting location **202** and the ending location **204** as well as their relationships with respect to a given set of constraints. In this example, trajectory **208** may be able to provide the shortest distance between the starting location **202** and the ending location **204**, but it may fail to comply with a location-based constraint **206** that establishes a restricted airspace. Trajectory **210** may be able to bypass the location-based constraint **206** while still arrive at the ending location **204** within a pre-specified time range, but it may not be able to avoid a storm **218** (a weather-based constraint) reportedly heading towards the direction of travel. Trajectory **212**, on the other hand, may be able to bypass the location-based constraint **206**, arrive at the ending location **204** within a pre-specified time range, and does not intersect with the detected path of the storm **218**. Therefore, trajectory **212** may be deemed to be the optimal trajectory between the starting location **202** and the ending location **204** for this set of constraints. It is understood, however, that the constraints listed above are merely exemplary. Various other types of constraints (e.g., avoiding traffics, comply with performance requirements or the like) may be taken into consideration by the trajectory planning method **100**.

In one embodiment, step **106** may analyze the set of constraints to determine an optimal trajectory between the starting location and the ending location. If one or more feasible trajectories (i.e., trajectories that comply with the constraints) are found between the starting location and the ending location, then an optimal trajectory may be selected from the feasible trajectories. It is contemplated that different operators may utilize different objective functions for selecting the optimal trajectory. For instance, if two feasible trajectories are both fully in compliance with the constraints, one operator may prefer the trajectory that utilizes the least amount of fuel (provided that all other constraints are satisfied) while another operator may prefer another trajectory that provides the least amount of flight time (provided that all other constraints are satisfied). Once the optimal trajectory is selected, the aircraft may be directed to operate according to the selected optimal trajectory.

On the other hand, a notice may be generated if no feasible trajectory exists between the starting location and the ending location (i.e., no trajectory would fully satisfy all of the constraints). Alternatively, certain constraints may be given higher importance levels than other constraints, in this manner, one or more potential trajectories may be provide with indications of the constraints that are not satisfied. For instance, if it is not feasible to bypass a restricted airspace and still satisfy the time constraints, and suppose that compliance with the restricted airspace is deemed more important, then a potential trajectory that bypasses the restricted airspace but arrives at a time later than expected may be provided with an indication that the time constraints are not satisfied. That is, step **106** may try to find an optimal trajectory that is in compliance with all constraints first. If not all constraints can be satisfied, step **106** may then try to find a trajectory that may comply with as many constraints as possible (preferably constraints with higher importance levels), which may be considered as the optimal trajectory for the given set of constraints.

The aircraft may operate based on the optimal trajectory determined in step **106**. However, it is contemplated that some constraints may change while the aircraft is in flight. For example, the opening and closing of special use airspace (daily and/or seasonally) may allow more direct routing and may happen after an aircraft has been dispatched. In another example, necessary path adjustments during a delegated separation maneuver may require an assessment of traffic, terrain or the like in order to choose path alternatives while still ensuring that the required time of arrival (RTA) can be maintained. Time of arrival may be expressed in various terms including, but not limited to, estimated time of arrival (ETA), contracted time of arrival (CTA), projected time of arrival (PTA), and their equivalents. In addition, other path constraints on the aircraft and other ground system described constraints may also change dynamically and therefore may be taken into consideration for dynamic trajectory planning.

FIG. **3** is an illustration depicting dynamic trajectory planning that takes into consideration the dynamic or real-time operational and environmental factors. In this example, the aircraft is en route to the ending location **204** according to trajectory **212** determined earlier. Suppose, for illustrative purposes, that the restricted airspace **206** is now open for public access, which effectively removes the location-based constraint that required the bypass before. In light of the opening of the restricted airspace **206**, trajectory **212** may no longer be the optimal trajectory between the current location **214** of the aircraft and the ending location **204**. Instead, a direct path from the current location **214** of the aircraft to the ending location **204**, provided that the direct path is still in compliance with other constraints (e.g., it still does not intersect with the path of the storm **218**), may be deemed to be the updated optimal trajectory **216** for the set of updated constraints. The flight of the aircraft may then be adjusted dynamically according to the update optimal trajectory **216**.

In one embodiment, step **108** may receive a set of updated constraints during flight of the aircraft. The updated constraint set may include new constraints that have been introduced or changes made to any previously received constraints. For example, if a new curfew is imposed while the aircraft is in flight, and if the existing trajectory is set to traverse through an area under the newly imposed curfew, the existing trajectory may need to be modified accordingly. In another example, suppose that the weather forecast provided prior to the departure was inaccurate, and if the existing trajectory is set to bypass a storm that no longer poses a threat, the existing trajectory may also be modified accordingly. It is understood that other constraint changes may also be received without departing from the spirit and scope of the present disclosure. Such constraints may include, but are not limited to, opening and closing of special use airspace, lifting and imposing of curfews, changes in traffic and terrain conditions, as well as various other constraints.

Step **110** may analyze the set of updated constraints to determine one or more feasible trajectories between the current location of the aircraft and the ending location. An optimal trajectory may be selected among the feasible trajectories similar to the selection process described above. If the optimal trajectory determined based on the updated constraints (referred to as the updated trajectory) is the same as the existing trajectory, then no change is needed. However, if the updated trajectory is different from the existing trajectory, step **112** may dynamically adjust the flight of the aircraft based on the updated trajectory. In one embodiment, the updated trajectory may be provided to a ground station for approval prior to adjusting the flight of the aircraft; and the flight of the aircraft may be adjusted based on the updated trajectory when it is approved. In addition, approved trajectories may be recorded in the System Wide Information Management (SWIM) or the like to facilitate sharing of air traffic management information.

It may be possible that no feasible trajectory can be found between the current location of the aircraft and the ending location that fully complies with all of the updated constraints. In this case, certain constraints may be given higher importance levels than other constraints as previously described. For instance, if the existing trajectory is set to traverse directly through a special use airspace which is now closed, the aircraft may have difficulty bypassing the closed special use airspace and still satisfy the time constraints. For illustrative purposes, suppose that compliance with the special use airspace constraint is deemed more important than the time constraints, then a potential trajectory that bypasses

the special use airspace but arrives at a time later than expected may be provided with an indication that the time constraints are not satisfied.

It is contemplated that steps **108** through **112** may be repeated as a continuous process during the flight of the aircraft in order to assess new constraints as they develop. Some constraints may expire and therefore may be removed from the constraint set. Furthermore, the path development capabilities of a traditional FMS may be utilized to facilitate the determination of path alternatives.

The trajectory planning method in accordance with the present disclosure may be performed utilizing a computer or processor (referred to as a constraint processor **402**) onboard the aircraft **400**, as shown in FIG. **4**. The constraint processor **402** is configured to fuse the constraints with the current trajectory and determine if the current trajectory need to be modified based on the given constraints. The constraint processor **402** may be communicatively connected (e.g., via various wired or wireless communication means) with other components of the aircraft **400**. For instance, the constraint processor **402** may be communicatively connected with navigation systems **404** for positional information, weather systems **406** for weather related information, communication systems **408** for ground and/or aerial communications, and various databases **410** that may provide recorded information such as terrain, known obstacles or the like. It is contemplated that the constraint processor **402** may be communicatively connected with other components (e.g., input devices **412** for receiving pilot inputs) onboard the aircraft **400** without departing from the spirit and scope of the present disclosure.

In one embodiment, to facilitate integration of various constraints, the constraint processor **402** may include a data interface configured for receiving inputs from various components and provide a set of uniformly formatted constraints to a processing module of the constraint processor **402**. An exemplary format may specify the following attributes for each constraint:

Field	Attribute
1	Identifier
2	4D Characteristics
3	Motion Characteristics
4	Error Characteristics
5	Aging Characteristics
6	Importance Level

For example, when information regarding a particular weather pattern (e.g., a storm) is received, such information may be assigned an identifier and the rest of the attributes may be populated based on the received information. For instance, the 4D characteristics (i.e., a three-dimensional space and a temporal dimension) may describe the location and time of the storm when it is detected; the motion characteristics may describe the movement of the storm; the error characteristics may describe the accuracy of the detection; the aging characteristics may describe whether the storm may decay over time; and the importance level may describe how important/critical it is for the aircraft to bypass the storm.

In another example, when traffic information regarding other aircraft nearby is received (e.g., via ADS-B, traffic radars, ground traffic control stations or the like), such information may also be assigned an identifier and the rest of the attributes may be populated based on the received traffic information. For instance, the 4D characteristics may describe the location and time of the other aircraft; the motion characteristics may describe the movement of the traffic; the error characteristics may describe the accuracy of the detection; the aging characteristics may describe when the other aircraft is no longer a concern. The importance level of this constraint, for example, may be higher than that of the weather constraint (in the example above).

The importance level may be predetermined based on the types of constraints. For example, a traffic constraint (e.g., avoiding traffic collations) may take precedence over avoiding a weather pattern. Alternatively/additionally, the importance levels may be assigned systematically based on various factors including the characteristics (e.g., error, aging and the like) of the constraints. For example, a traffic constraint that is going to expire shortly may not be as important as a weather constraint that indicates a severe storm directly ahead of the direction of travel of the aircraft. It is contemplated that different algorithms may be utilized for assigning importance levels without departing from the spirit and scope of the present disclosure.

It is also contemplated that not all constraints are required to specify every exemplary field described above, in which case the unspecified fields may be indicated as "null". For example, an established restricted area may be stationary and therefore may not have any motion characteristics. In another example, constraints such as minimizing fuel consumptions may not have any 4D and motion characteristics.

It is understood that the constraint format described above is merely exemplary. Different formatting standards may be utilized without departing from the spirit and scope of the present disclosure. Furthermore, it is understood that the types of constraints described above are merely exemplary. Various other types of constraints may be populated in a similar manner as describe. The types of constrains may include, but are not limited to, time-based constraints (e.g., minimizing fly time, required time of arrival, or the like), cost-based constraints (e.g., with respect to fuel consumptions or the like), location-based constraints (e.g., with respect to airspace availabilities or the like), weather-based constraints, terrain-based constraints, traffic-based constraints, or performance constraints.

It is understood that the present disclosure is not limited to any underlying implementing technology. The present disclosure may be implemented utilizing any combination of software and hardware technology. The present disclosure may be implemented using a variety of technologies without departing from the scope and spirit of the invention or without sacrificing all of its material advantages.

It is understood that the specific order or hierarchy of steps in the processes disclosed is an example of exemplary approaches. Based upon design preferences, it is understood that the specific order or hierarchy of steps in the processes may be rearranged while remaining within the scope of the present invention. The accompanying method claims present elements of the various steps in a sample order, and are not meant to be limited to the specific order or hierarchy presented.

It is believed that the present disclosure and many of its attendant advantages will be understood by the foregoing description, and it will be apparent that various changes may be made in the form, construction, and arrangement of the components thereof without departing from the scope and spirit of the invention or without sacrificing all of its material advantages. The form herein before described being merely an explanatory embodiment thereof, it is the intention of the following claims to encompass and include such changes.

What is claimed is:

1. A method performed by at least one processing unit onboard an aircraft, the method comprising:

receiving a starting location and an ending location for a phase of flight of an aircraft;

receiving a set of constraints for the phase of flight of the aircraft, wherein operations of the aircraft during the phase of flight are subject to the set of constraints, and wherein each particular constraint of the set of constraints includes: an error attribute specifying a likelihood of errors associated with said particular constraint and an aging attribute specifying an expiration time of said particular constraint;

assigning to each particular constraint of the set of constraints an importance level based on at least the error attribute and the aging attribute of said particular constraint, wherein a relatively lower likelihood of errors associated with said particular constraint and a relatively longer time remaining till the expiration time of said particular constraint correspond to a relatively higher importance level assignment of said particular constraint;

analyzing the set of constraints to determine an optimal trajectory between the starting location and the ending location, the optimal trajectory being determined based on compliance with the set of constraints, wherein when the set of constraints cannot be satisfied simultaneously, a trajectory that satisfies a maximum number of relatively higher importance level constraints in the set of constraints is deemed the optimal trajectory; and

directing the aircraft to operate according to the optimal trajectory determined.

2. The method of claim **1**, further comprising:

receiving a set of updated constraints during the flight of the aircraft;

analyzing the set of updated constraints to determine an updated trajectory between a current location of the aircraft and the ending location, the updated trajectory is determined based on compliance with the set of updated constraints; and

dynamically adjusting the flight of the aircraft based on the updated trajectory.

3. The method of claim **2**, further comprising:

waiting for approval of the updated trajectory prior to dynamically adjusting the flight of the aircraft based on the updated trajectory.

4. The method of claim **1**, wherein the set of constraints include at least one of: a time-based constraint, a cost-based constraint, a location-based constraint, a weather-based constraint, a terrain-based constraint, a traffic-based constraint, or a performance constraint.

5. The method of claim **1**, further comprising:

indicating a set of unsatisfied constraints to the operator when the set of constraints cannot be satisfied simultaneously, the set of unsatisfied constraints being a subset of the set of constraints.

6. The method of claim **1**, wherein the set of constraints is formatted uniformly.

7. The method of claim **6**, wherein each one of the set of constraints includes at least one of: an identifier field, a dimensional characteristics field, a motion characteristics field, an error characteristics field, an aging characteristics field, or an importance level field.

8. A method performed by at least one processing unit onboard an aircraft, the method comprising:

receiving a starting location and an ending location for a phase of flight of an aircraft;

receiving a set of constraints for the phase of flight of the aircraft, the set of constraints including at least one of: a time-based constraint, a cost-based constraint, a location-based constraint, a weather-based constraint, a terrain-based constraint, a traffic-based constraint, or a performance constraint, wherein each particular constraint of the set of constraints includes: an error attribute specifying a likelihood of errors associated with said particular constraint and an aging attribute specifying an expiration time of said particular constraint;

assigning to each particular constraint of the set of constraints an importance level based on at least the error attribute and the aging attribute of said particular constraint, wherein a relatively lower likelihood of errors associated with said particular constraint and a relatively longer time remaining till the expiration time of said particular constraint correspond to a relatively higher importance level assignment of said particular constraint;

analyzing the set of constraints to determine an optimal trajectory between the starting location and the ending location, the optimal trajectory being determined based on compliance with the set of constraints, wherein when the set of constraints cannot be satisfied simultaneously, a trajectory that satisfies a maximum number of relatively higher importance level constraints in the set of constraints is deemed the optimal trajectory; and

directing the aircraft to operate according to the optimal trajectory determined.

9. The method of claim **8**, further comprising:

receiving a set of updated constraints during the flight of the aircraft;

analyzing the set of updated constraints to determine an updated trajectory between a current location of the aircraft and the ending location, the updated trajectory is determined based on compliance with the set of updated constraints; and

dynamically adjusting the flight of the aircraft based on the updated trajectory.

10. The method of claim **9**, further comprising:

waiting for approval of the updated trajectory prior to dynamically adjusting the flight of the aircraft based on the updated trajectory.

11. The method of claim **8**, wherein the time-based constraint specifies a pre-specified time range, the cost-based constraint specifies a fuel consumption requirement, the location-based constraint specifies availability of at least one airspace, the weather-based constraint specifies at least one weather-related event to avoid, the terrain-based constraint specifies at least one terrain condition to avoid, the traffic-based constraint specifies at least one traffic condition to avoid, and the performance constraint specifies a performance-based navigation specification.

12. The method of claim **8**, further comprising:

indicating a set of unsatisfied constraints to the operator when the set of constraints cannot be satisfied simultaneously, the set of unsatisfied constraints being a subset of the set of constraints.

13. The method of claim **8**, wherein the set of constraints is formatted uniformly.

14. The method of claim **13**, wherein each one of the set of constraints includes at least one of: an identifier field, a dimensional characteristics field, a motion characteristics field, an error characteristics field, an aging characteristics field, or an importance level field.

15. An apparatus for providing trajectory planning on an aircraft, the apparatus comprising:

a data interface configured to:

receive a starting location and an ending location for a phase of flight of an aircraft; and

receive a set of constraints for the phase of flight of the aircraft, wherein each particular constraint of the set of constraints includes: an error attribute specifying a likelihood of errors associated with said particular constraint and an aging attribute specifying an expiration time of said particular constraint;

a processor communicatively connected with the data interface, the processor configured to:

assign to each particular constraint of the set of constraints an importance level based on at least the error attribute and the aging attribute of said particular constraint, wherein a relatively lower likelihood of errors associated with said particular constraint and a relatively longer time remaining till the expiration time of said particular constraint correspond to a relatively higher importance level assignment of said particular constraint; and

analyze the set of constraints to determine at least one optimal trajectory between the starting location and the ending location, the at least one optimal trajectory being determined based on compliance with the set of constraints, wherein when the set of constraints cannot be satisfied simultaneously, a trajectory that satisfies a maximum number of relatively higher importance level constraints in the set of constraints is deemed the at least one optimal trajectory; and

a user interface configured to present the at least one optimal trajectory for selection by a user.

16. The apparatus of claim **15**, wherein the set of constraints include at least one of: a time-based constraint, a cost-based constraint, a location-based constraint, a weather-based constraint, a terrain-based constraint, a traffic-based constraint, or a performance constraint.

17. The apparatus of claim **16**, wherein the time-based constraint specifies a pre-specified time range, the cost-based constraint specifies a fuel consumption requirement, the location-based constraint specifies availability of at least one airspace, the weather-based constraint specifies at least one weather-related event to avoid, the terrain-based constraint specifies at least one terrain condition to avoid, the traffic-based constraint specifies at least one traffic condition to avoid, and the performance constraint specifies a performance-based navigation specification.

18. The apparatus of claim **15**, wherein the user interface is further configured to indicate a set of unsatisfied constraints to the user when the set of constraints cannot be satisfied simultaneously, the set of unsatisfied constraints being a subset of the set of constraints.

19. The apparatus of claim **15**, wherein the data interface is further configured to format the set of constraints prior to providing the set of constraints to the processor.

20. The apparatus of claim **19**, wherein each one of the set of formatted constraints includes at least one of: an identifier field, a dimensional characteristics field, a motion characteristics field, an error characteristics field, an aging characteristics field, or an importance level field.

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